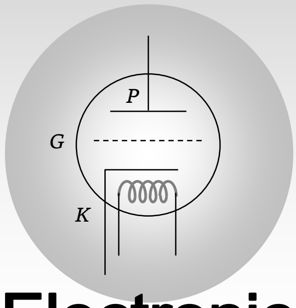


Valve & Digital Electronics

Do You Know

(1) Electronics can be devided in two categories

(i) Valve electronics (ii) Semiconductor electronics

(2) Free electron in metal experiences a barrier on surface due to attractive Coulombian force.

(3) When kinetic energy of electron becomes greater than barrier potential energy (or binding energy E_b) then electron can come out of the surface of metal.

(4) **Fermi energy (E_f)**

Is the maximum possible energy possessed by free electron in metal at $0K$ temperature

(i) In this energy level, probability of finding electron is 50%.

(ii) This is a reference level and it is different for different metals.

(5) **Threshold energy (or work function W_o)**

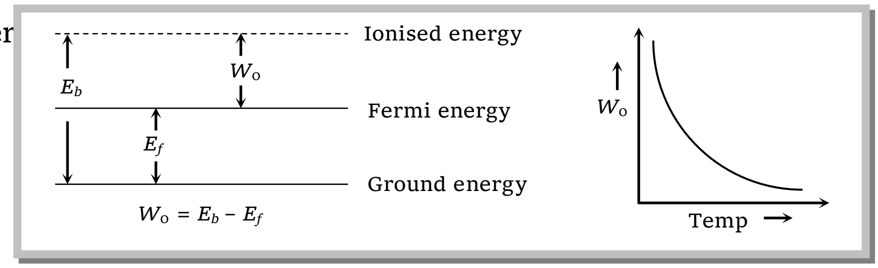
Is the minimum energy required to take out an electron from the surface of metal. Also $W_o = E_b - E_f$

Work function for different mater

$(W_o)_{\text{Pure tungsten}} = 4.5\ eV$

$(W_o)_{\text{Throated tungsten}} = 2.6\ eV$

$(W_o)_{\text{Oxide coated tungsten}} = 1\ eV$



(6) **Electron emission**

Four process of electron emission from a metal are

(i) Thermionic emission (ii) Photoelectric emission (iii) Field emission (iv) Secondary emission

Thermionic Emission and Emitters

(1) **Thermionic emission**

(i) The phenomenon of ejection of electrons from a metal surface by the application of heat is called thermionic emission and emitted electrons are called thermions and current flowing is called thermion current.

(ii) Thermions have different velocities.

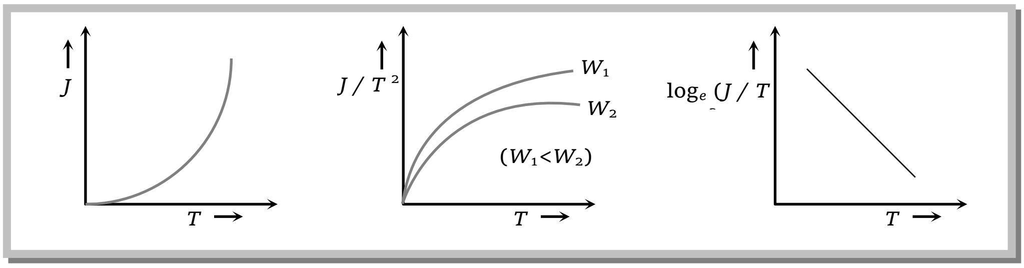
(iii) This was discovered by Edison

(iv) Richardson – Dushman equation for current density (*i.e.* electric current emitted per unit area of metal surface) is given as $J = AT^2 e^{-W_0/kT} = AT^2 e^{-\frac{qV}{kT}} = AT^2 e^{-\frac{11600\,V}{T}}$

where A = emission constant = 12×10^4 $amp/\ m^2\text{-}K^2$, k = Boltzmann's constant, T = Absolute temp and W_0 = work function.

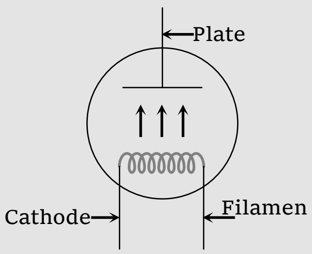
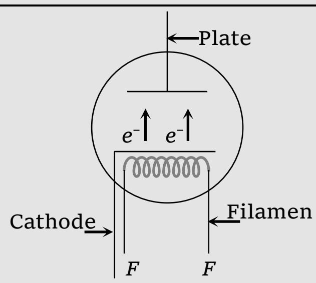
(v) The number of thermions emitted per second per unit area (J) depends upon following :

(a) $J \propto T^2$ (b) $J \propto e^{-W_0}$



(2) **Thermionic emitters**

The electron emitters are of two types

Directly heated emitter	Indirectly heated emitter
	
(i) Cathode is directly heated by passing current.	(i) Cathode is indirectly heated.
(ii) Thermionic current is less.	(ii) Thermionic current is more.
(iii) Energy consumption and life is small.	(iii) Energy consumption and life is more.

Note : ❑ A good emitter should have low work function, high melting point, high working temperature, high electrical and mechanical strength.

Vacuum Tubes and Thermionic Valves

(1) Those tubes in which electrons flows in vacuum are called vacuum tubes.

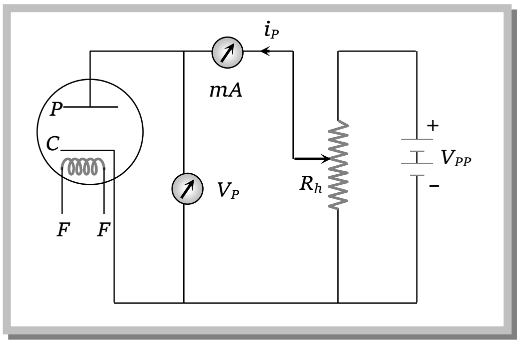
(2) These are also called valves because current flow in them is unidirectional.

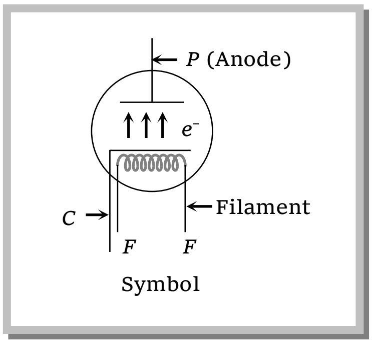
(3) Vacuum in vacuum tubes prevents the emission of secondary electrons.

(4) Every vacuum tube necessarily contains two electrodes out of which one is always electron emitter (cathode) and another one is electron collector (anode or plate).

(5) Depending upon the number of electrodes used the vacuum tubes are named as diode, triode, tetrode, pentode.... respectively, if the number of electrodes used are 2, 3, 4, 5..... respectively.

Diode Valve





Inventor : Fleming

Principle : Thermionic emission

Number of electrodes : Two

Working : When plate potential (V_p) is positive, plate current (i_p) flows in the circuit (because some emitted electrons reaches to plate). If + V_p increases i_p also increases and finally becomes maximum (saturation).

Note : ❑ If $V_p \rightarrow$ Negative; No current will flow

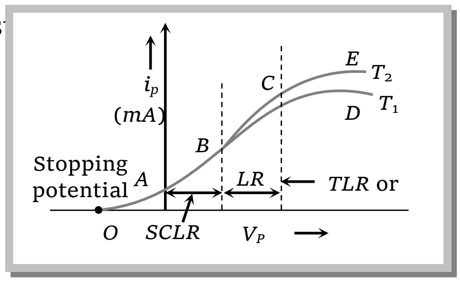
❑ If $V_p \rightarrow$ Zero; current flows due to very less number of highly energised electrons

(1) **Space charge**

If V_p is zero or negative, then electrons collect around the plate as a cloud which is called space charge. space charge decreases the emission of electrons from the cathode.

(2) **Characteristic curve of a diode**

A graph represents the variation of i_p with V_p at a given filament current (i_f) is known as characteris



The curve is not linear hence diode valve is known as non-ohmic device.

(i) **Space charge limited region (SCLR)** : In this region current is space charge limited current. Also $i_p \propto V_p^{3/2} \Rightarrow i_p = kV_p^{3/2}$; where k is a constant depending on metal as well as on the shape and area of the cathode. This is called child's law.

(ii) **Linear region (LR) :** $i_p \propto V_p$

(iii) **Saturated region or temperature limited region :** In this part, the current is independent of potential difference applied between the cathode and anode.

$i_p \neq f(V_p)$ $i_p = f$ (temperature)

The saturation current follows Richardson Dushman equation *i.e.* $i = AT^2 e^{-\phi/kT}$

Note : ❑ The small increase in i_p after saturation stage due to field emission is known as Shottkey effect.

(iv) **Diode resistance**

(a) Static plate resistance or dc plate resistance : $R_p = \dfrac{V_p}{i_p}$.

(b) Dynamic or ac plate resistance : If at constant filament current, a small change ΔV_P in the plate potential produces a small change Δi_p in the plate current, then the ratio $\Delta V_p / \Delta i_p$ is called the dynamic resistance, or the 'plate resistance' of the diode $r_p = \dfrac{\Delta V_p}{\Delta i_p}$.

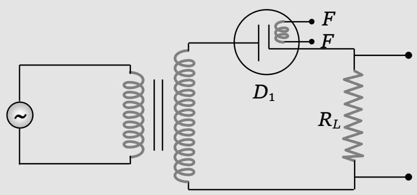
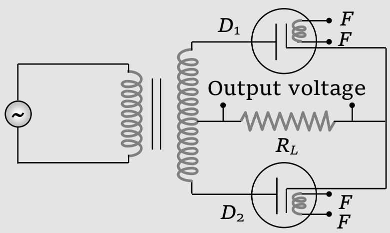
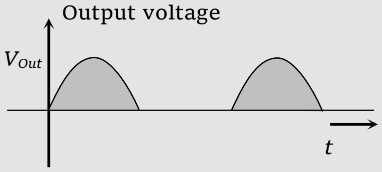
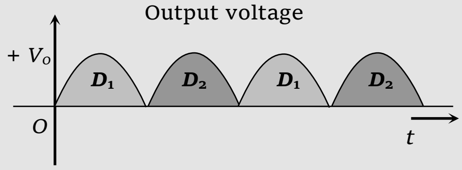
Note : ❑ In SCLR $r_p < R_p$, In TLR $R_p < r_p$ and $r_p = \infty$.

(3) **Uses of diode valve**

(i) As a rectifier (ii) As a detector (iii) As a transmitter (iv) As a modulator

(4) **Diode valve as a rectifier**

Rectifier is a device which is used to convert ac into dc

S. No.	Half wave rectifier	Full wave rectifier
(i)		
(ii)		

(iii)	$I_{av} = I_{dc} = \frac{I_0}{\pi}$ and $E_{av} = E_{dc} = \frac{V_0}{\pi}$	$I_{av} = \frac{2I_0}{\pi}$ and $E_{av} = \frac{2V_0}{\pi}$
(iv)	Ripple factor $r = \sqrt{\left(\frac{i_{rms}}{i_{dc}}\right)^2 - 1} = 1.21$	$r = 0.48$
(v)	$i_{rms} = \frac{i_0}{2}$	$i_{rms} = \frac{i_0}{\sqrt{2}}$
(vi)	Value of peak load current $= \frac{V_0}{r_p + R_L}$	$\frac{V_0}{r_p + R_L}$
(vii)	dc component in output voltage as compared to input ac voltage – less	More
(viii)	Efficiency $\eta = \frac{0.406}{1 + \frac{r_p}{R_L}}$	$= \frac{0.812}{1 + \frac{r_p}{R_L}}$
(ix)	Form factor = 1.57	1.11
(x)	Ripple frequency – equal to the frequency of input ac	Double the frequency of input ac

(5) **Filter circuit**

Filter circuits smooth out the fluctuations in amplitude of ac ripple of the output voltage obtained from a rectifier.

(i) Filter circuit consists of capacitors or/ and choke coils.

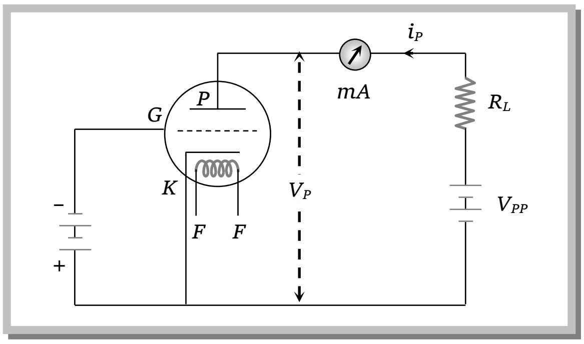
(ii) A capacitor offers a high resistance to low frequency ac ripple (infinite resistance to dc) and a low resistance to high frequency ac ripple. Therefore, it is always used as a shunt to the load.

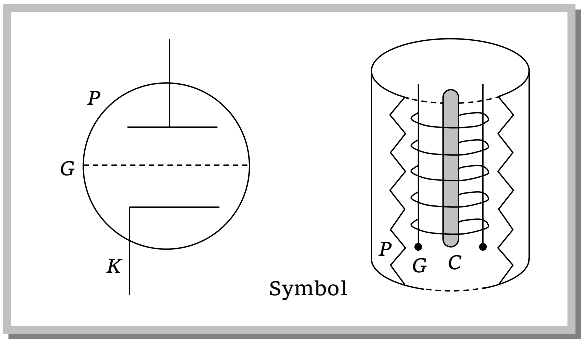
(iii) A choke coil offers high resistance to high frequency ac, and almost zero resistance to dc. It is used in series.

(iv) π – Filter is best for ripple control.

(v) For voltage regulation choke input filter (L-filter) is best.

Triode Valve





Inventor : Dr. Lee De Forest

Principle : Thermionic emission

Number of electrodes : Three

Grid : Is a third electrode, also known as control grid, which controls the electrons going from cathode to plate. It is kept near the cathode with low negative potential.

Working : Plate of triode valve is always kept at positive potential *w.r.t.* cathode. The potential of plate is more than that of grid. The variation of plate potential affects the plate current as follows $i_p = k\left(V_G + \frac{V_p}{\mu}\right)^{3/2}$; where μ = Amplification factor of triode valve, k = Constant of triode valve.

When grid is given positive potential then plate current increases but in this case triode cannot be used for amplifier and therefore grid is normally not given positive potential.

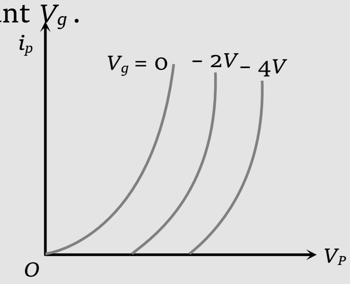
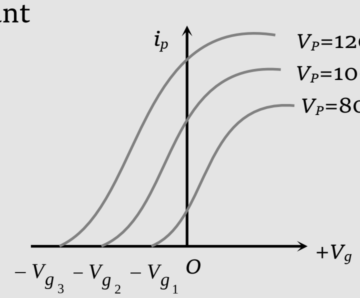
When grid is given negative potential then plate current decreases but in this case grid controls plate current most effectively.

(1) **Cut off grid voltage :** The valve of V_G for which the plate current becomes zero is known as the cut off voltage. For a given V_p, it is given by $V_G = -\frac{V_p}{\mu}$.

(2) **Characteristic of triode :** These are of two types

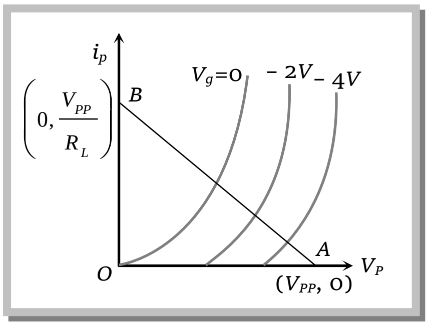
Static characteristic	Dynamic characteristic
Graphical representation of V_p or V_g and i_p without any load	Graphical representation of V_p or V_g and i_p with load

Note : ❑ Both static and dynamic characteristics are again of two types-plate characteristics and mutual characteristic

Static plate (or anode) characteristic	Static mutual (or trans) characteristics
Graphical representation of i_p and V_P at constant V_g. 	Graphical representation of i_P and V_G when V_P is kept constant 

Load line

(a) It is a straight line joining the points (V_{pp} , 0) on plate voltage axis and $(0, V_{pp}/R_L)$ on plate current axis of plate characteristics of triode.



(b) In graph, AB is a load line and the equation of load line is :

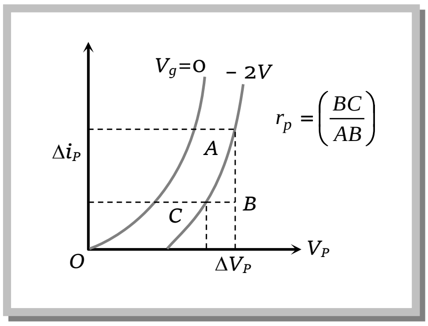
$$V_{pp} = i_p R_L + V_p \text{ or } i_P = -\frac{1}{R_L} V_P + \frac{V_{PP}}{R_L}$$

(c) The slope of load line $AB = \frac{di_p}{dV_p} = -\frac{1}{R_L}$

(d) In graph, $OA = V_{pp}$ =intercept of load line on V_P axis and $OB = V_{pp}/R_L$ =intercept of load line on i_p axis.

(3) **Constant of triode valve**

(i) **Plate or dynamic resistance (r_P) :** The slope of plate characteristic curve is equal to $\frac{1}{\text{plate resistance}}$ or It is the ratio of small change in plate voltage to the change in plate current produced by it, the grid voltage remaining constant. That is, $r_p = \frac{\Delta V_p}{\Delta i_p}, V_G = \text{constant}$.

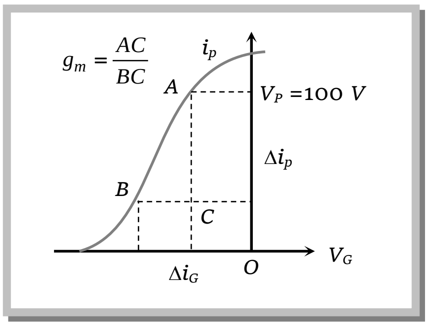


It is expressed in kilo ohms ($K\Omega$). Typically, it ranges from about 8 $K\Omega$ to 40 $K\Omega$. The r_p can be determined from plate characteristics. It represents the reciprocal of the slope of the plate characteristic curve.

If the distance between plate and cathode is increased the r_p increases. The value of r_p is infinity in the state of cut off bias or saturation state.

(ii) **Mutual conductance (or trans conductance) (g_m)**

(a) It is defined as the ratio of small change in plate current (Δi_p) to the corresponding small change in grid potential (ΔV_g) when plate potential V_p is kept constant *i.e.* $g_m = \left(\frac{\Delta i_p}{\Delta V_g}\right)_{V_p \text{ is constant}}$



(b) The value of g_m is equal to the slope of mutual characteristics of triode.

(c) The value of g_m depends upon the separation between grid and cathode. The smaller is this separation, the larger is the value of g_m and vice versa.

(d) In the saturation state, the value of $\Delta i_p = 0$, $g_m = 0$

(iii) **Amplification factor (μ) :** It is defined as the ratio of change in plate potential (ΔV_p) to produce certain change in plate current (Δi_p) to the change in grid potential (ΔV_g) for the same change in plate current (Δi_p) *i.e.* $\mu = -\left(\frac{\Delta V_p}{\Delta V_g}\right)_{\Delta I_p = \text{a constant}}$; negative sign indicates that V_p and V_g are in opposite phase.

(a) Amplification factor depends upon the distance between :

- Plate and cathode (d_{pk}) • Plate and grid (d_{pg}) • Grid and cathode (d_{gk})

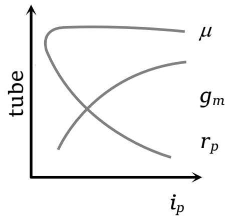
Also $\mu \propto d_{pg} \propto d_{pk} \propto \frac{1}{d_{gk}}$

(b) The value of μ is greater than one.

(c) Amplification factor is unitless and dimensionless.

Note : ❑ The triode constants are not independent of each other. They are related by the relation.

$$\mu = r_p \times g_m$$



The r_p and g_m depends on i_p in the following manner.

$r_p \propto i_p^{-1/3}$, $g_m \propto i_p^{1/3}$

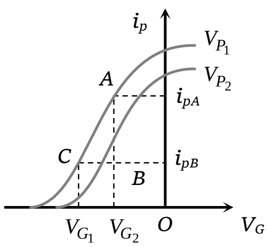
μ does not depend on i_p. The variation of triode parameters with i_p are shown in figure.

❑ Above three constant may be determined from any one set of characteristic curves.

$$r_p = \frac{V_{P1} - V_{P2}}{I_{PA} - I_{PB}},$$

$$g_m = \frac{I_{PA} - I_{PB}}{V_{G1} - V_{G2}},$$

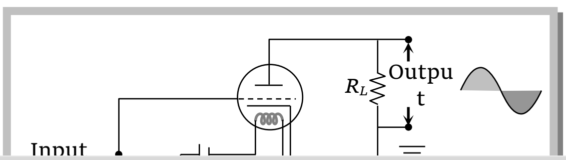
$$\mu = -\frac{V_{P1} - V_{P2}}{V_{G2} - V_{G1}}$$



(4) **Triode as an Amplifiers**

Amplifier is a device by which the amplitude of variation of *ac* signal voltage / current/ power can be increased

(i) **Principle and circuit diagram :** The amplifying action of the triode is based on the fact that small change in grid voltage produces the same change in the grid voltage as due to a large change in the plate voltage. A circuit for triode as an amplifier



(ii) **Working :** First of all the mutual characteristic curves of a triode to be used as an amplifier are plotted and the grid potential – Vg_b corresponding to the mid-point of straight portion of characteristic curve is noted.

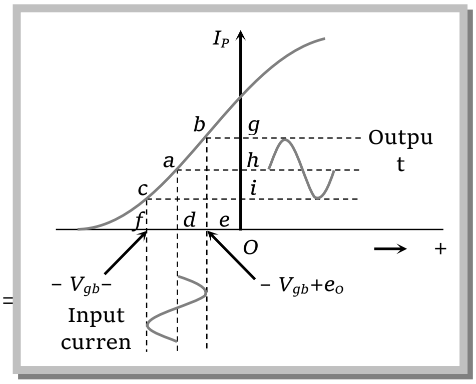
This negative grid potential is applied on grid and is known as grid bias. The AC signal to be amplified is connected in series with this grid bias $(-Vg_b)$. Let the input signal be represented as $e_g = e_0 \sin \omega t$.

The net input grid voltage $= -Vg_b + e_0 \sin \omega t$, varies between $-Vg_b + e_0$ and $-Vg_b - e_0$. The corresponding amplified output current shown in fig. The output voltage is taken across load resistance R_L. If e_g (or ΔVg) is the input signal voltage and $\Delta V_L = R_L i_p (= R_L \Delta i_p)$ is the consequent voltage change across load R_L, then

$$\text{Voltage gain} = \frac{\text{output voltage}}{\text{input voltage}} = \frac{\Delta V_L}{\Delta V_g} = \frac{\Delta V_p}{\Delta V_g} = \frac{\mu R_L}{R_p + R_L}$$

or $A = \dfrac{\mu}{1 + R_p / R_L}$

The maximum voltage gain is obviously equal to μ for $R_L =$



Example

***Example*: 1** The peak voltage in the output of a half-wave diode rectifier fed with a sinusoidal signal without filter is 10V. The d.c. component of the output voltage is

(a) $20/\pi V$ (b) $10/\sqrt{2}\ V$ (c) $10/\pi V$ (d) $10V$

Solution : (c) In half wave rectifier $V_{dc} = \dfrac{V_0}{\pi} = \dfrac{10}{\pi} volt$

***Example*: 2** When plate voltage of diode increased from 100 V to 150 V then plate current increases from 7.5mA to 12mA the AC plate resistance will be

(a) 10 $k\Omega$ (b) 11 $k\Omega$ (c) 15 $k\Omega$ (d) 11.1$k\Omega$

Solution : (d) ac plate resistance $r_P = \frac{\Delta V_P}{\Delta i_P} = \frac{150 - 100}{(12 - 7.5)\times 10^{-3}} = 11.1 k\Omega$

Example: 3 In the grid circuit of the triode a signal $E = 2\sqrt{2}$ cos $\omega\, t$ is applied if $\mu = 14, r_p = 10 K\Omega$ then the current **[RPMT 1992]**

(a) 1.27 *mA* (b) 10 *mA* (c) 1.5 *mA* (d) 12.4 *mA*

Solution : (a) $i_P = \frac{\mu \times V_g}{r_P + R_L}$; From voltage applied across grid, peak voltage $V_0 = V_g = 2\sqrt{2}\, volt$

$i_P = \frac{14 \times 2\sqrt{2}}{(10 + 12)\times 10^3} = 1.27\, mA$.

Example: 4 A triode having $\mu = 18$ and $r_p = 8000$ *ohm* is used as an amplifier with a load resistance of 10 kilo ohm in the plate circuit. The voltage amplification is, then

(a) 1 (b) 10 (c) 20 (d) 30

Solution : (b) From $A_V = \frac{\mu R_L}{r_P + R_L} = \frac{18 \times 10 \times 10^3}{18 \times 10^3} = 10$

Example: 5 Keeping the grid voltage constant, a change in the plate potential of 50 *V*, changes the plate current by 10 *mA*. And keeping the plate potential constant, a change in the grid potential of 2 *V*, changes the plate current by 10 *mA* again. The amplification factor of the triode will be **[CBSE 1991]**

(a) 100 (b) 25 (c) 5 (d) 20

Solution : (b) $r_P = \left(\frac{\Delta V_P}{\Delta i_P}\right)_{V_g} = \frac{50}{10 \times 10^{-3}} = 5 \times 10^3 \Omega$ and $g_m = \left(\frac{\Delta i_p}{\Delta V_g}\right)_{V_P} = \frac{10 \times 10^{-3}}{2} = 5 \times 10^{-3} \Omega^{-1}$

$\therefore\ \mu = r_P \times g_m = 5 \times 10^3 \times 5 \times 10^{-3} = 25$

Example: 6 A diode valve works in the region of space charge limited current. If the voltage is increased four times, how many times the space charge limited current will increase

(a) Will remain unchanged (b) 2 (c) 8 (d) 4

Solution : (c) From $i \propto V^{3/2} \Rightarrow \frac{i_2}{i_1} = \left(\frac{V_2}{V_1}\right)^{3/2} = \left(\frac{4}{1}\right)^{3/2} = 8$

Example: 7 A triode whose mutual conductance is 2.5 *m A/volt* and anode resistance is 20 *kilo ohm*, is used as an amplifier whose amplification is 10. The resistance connected in plate circuit will be **[MP PET 1989; RPMT 1998]**

(a) 1 *k*Ω (b) 5 *k*Ω (c) 10 *k*Ω (d) 20 *k*Ω

Solution : (b) $A = \frac{\mu R_L}{r_P + R_L} \Rightarrow r_P + R_L = \frac{\mu R_L}{A} = \frac{50 R_L}{10} = 5 R_L$

$\mu = r_P \times g_m = 20 \times 22.5 = 50$

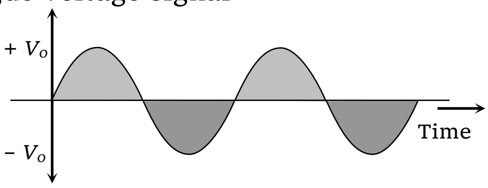
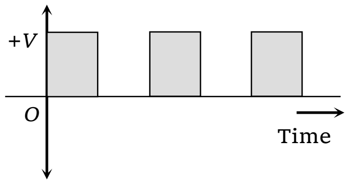
From $A = \frac{\mu R_L}{r_P + R_L} \Rightarrow r_P + R_L = \frac{\mu R_L}{A} = \frac{50 R_L}{10} = 5 R_L$

$\therefore\ 4 R_L = \frac{r_P}{4} = \frac{20}{5} = 5 k\Omega$

Digital Electronics

Voltage Signal and Binary System

(1) **Voltage signal**

Analogue voltage signal	Digital voltage signal
The signal which represents the continuous variation of voltage with time is known as analogue voltage signal 	The signal which has only two values. *i.e.* either a constant high value of voltage or zero value is called digital voltage signal 

(2) **Binary system**

(i) A number system which has only two digits *i.e.* 0 (Low value) and 1 (High value) is known as binary system

(ii) The electrical circuit which operates only in these two state *i.e.* 1 (On or High) and 0 (*i.e.* Off or Low) are known as digital circuits.

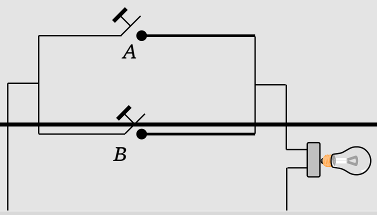
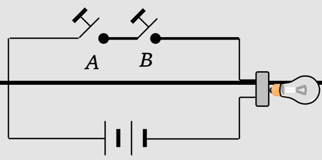
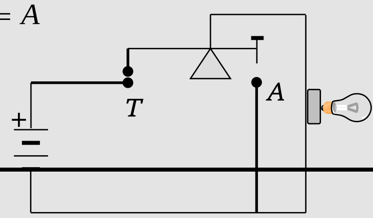
(iii) Different names for the two states of digital signals :

State Code	Name for the State							
1	On	Up	Closed	Excited	True	Pulse	High	Yes
0	Off	Down	Open	Unexcited	False	No pulse	Low	No

Boolean Algebra

(1) In Boolean algebra only two states of variables (0 and 1) are allowed.

(2) The variables (A, B, C ....) of Boolean Algebra are subjected to three operations.

	OR Operation	AND Operation	NOT Operation
(i)	Represented by (+) sign	Represented by (·) sign	Represented by bar over the variables
(ii)	Boolean expression $Y = A + B$ 	Boolean expression $Y = A \cdot B$ 	Boolean expression $Y = \overline{A}$  A OFF → Lamp ON

(3) **Basic Boolean postulates and laws**

(i) Boolean Postulates : $0 + A = A$, $1 \cdot A = A$, $1 + A = 1$, $0 \cdot A = 0$, $A+\overline{A}=1$

(ii) Identity law : $A + A = A$, $A \cdot A = A$

(iii) Negation law : $\overline{\overline{A}} = A$

(iv) Commutative law : $A + B = B + A$, $A \cdot B = B \cdot A$

(v) Associative law : $(A+B) + C = A + (B+C)$, $(A \cdot B) \cdot C = A \cdot (B \cdot C)$

(vi) Distributive law : $A \cdot (B+C) = A \cdot B + A \cdot C$

(vii) De Morgan's laws : $\overline{A+B}=\overline{A}\cdot\overline{B}$ and $\overline{A\cdot B}=\overline{A}+\overline{B}$ also $A+\overline{A}B=A+B$ and $A(\overline{A}+B)=AB$

Logic Gates and Truth Table

(1) **Logic gate :** The digital circuit that can be analysed with the help of Boolean algebra is called logic gate or logic circuit. A logic gate has two or more inputs but only one output.

There are primarily three logic gates namely the OR gate, the AND gate and the NOT gate.

(2) **Truth table :** The operation of a logic gate or circuit can be represented in a table which contains all possible inputs and their corresponding outputs is called the truth table. To write the truth table we use binary digits 1 and 0.

Different Logic Gates

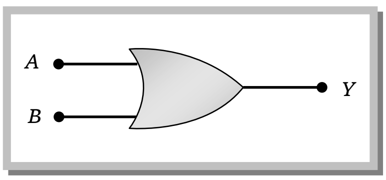
(1) **The 'OR' gate**

(i) It has two inputs (A and B) and only one output (Y)

(ii) Boolean expression is $Y = A + B$

(iii) Truth table and logic symbol

A	B	$Y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1



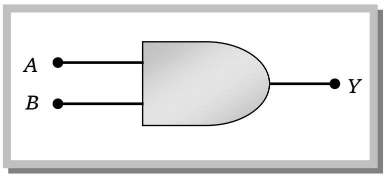
(2) **The 'AND' gate**

(i) It has two inputs and one output.

(ii) Boolean expression is $Y = A \cdot B$

(iii) Truth table and logic symbol :

A	B	$Y = A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1



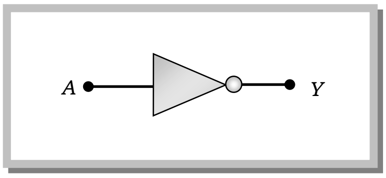
(3) **The 'NOT' gate**

(i) It has only one input and only one output

(ii) Boolean expression is $Y = \overline{A}$

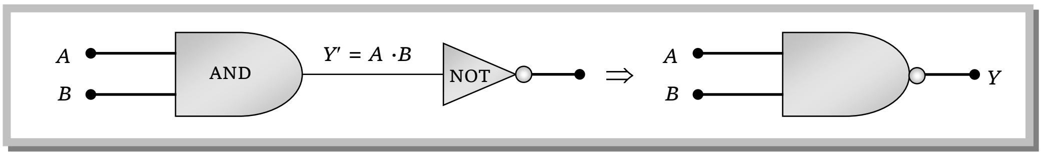
(iii) Truth table and logic symbol :

A	$Y = \overline{A}$
0	1
1	0



Combination of Logic Gates

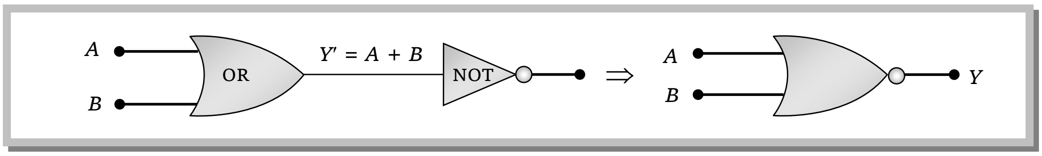
(1) **The 'NAND' gate :** From 'AND' and 'NOT' gate



Boolean expression and truth table : $Y = \overline{A \cdot B}$

A	B	$Y' = A \cdot B$	Y
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

(2) **The 'NOR' gate :** From 'OR' and 'NOT' gate



Boolean expression and truth table : $Y = \overline{A + B}$

A	B	$Y' = A + B$	Y

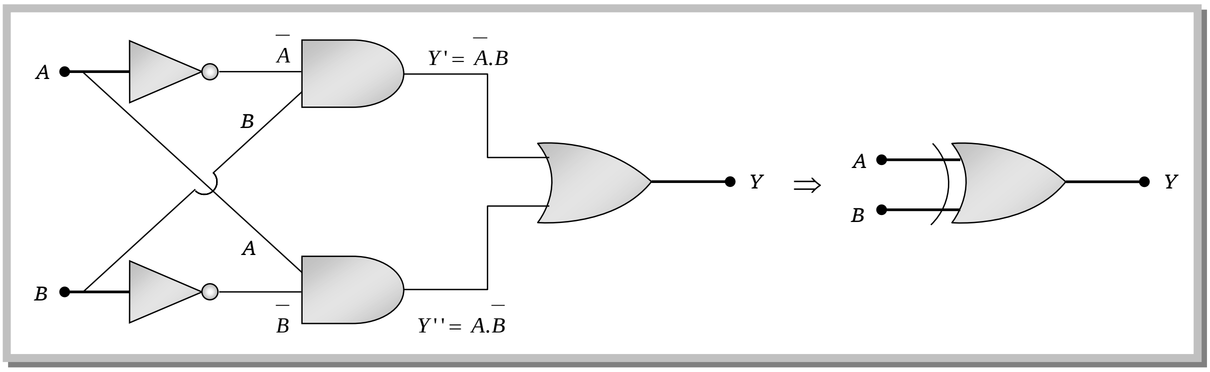
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

(3) **The 'XOR' gate :** From 'NOT', 'AND' and 'OR' gate. Known as exclusive OR gate.

or

The logic gate which gives high output (*i.e.*, 1) if either input A or input B but not both are high (*i.e.* 1) is called exclusive OR gate or the XOR gate.

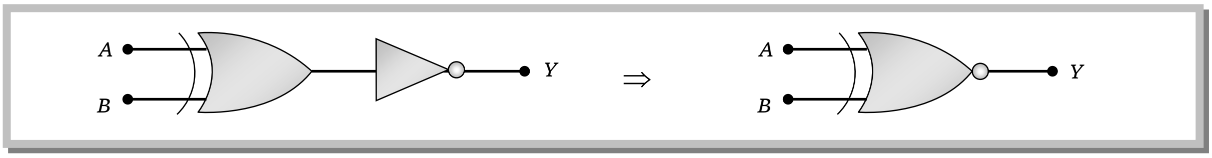
It may be noted that if both the inputs of the XOR gate are high, then the output is low (*i.e.*, 0).



Boolean expression and truth table : $Y = A \oplus B = \overline{A}B + \overline{AB}$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(4) **The exclusive nor (XNOR) gate :** XOR + NOT $\longrightarrow$ XNOR



Boolean expression : $Y = A \odot B = \overline{A}\,\overline{B} + AB$

Logic Gates Using 'NAND' Gate

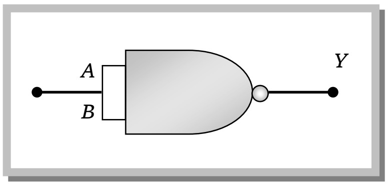
The NAND gate is the building block of the digital electronics. All the logic gates like the OR, the AND and the NOT can be constructed from the NAND gates.

(1) **Construction of the ' NOT' gate from the ' NAND' gate**

(i) When both the inputs (A and B) of the NAND gate are joined together then it works as the NOT gate.

(ii) Truth table and logic symbol

Input	Output
A = *B*	*Y*
0	1
1	0

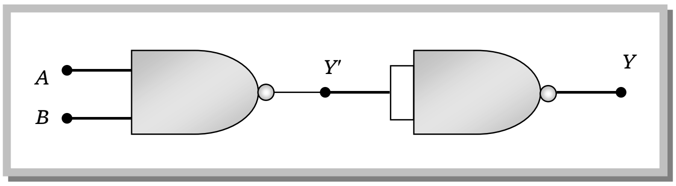


(2) **Construction of the 'AND' gate from the ' NAND' gate.**

(i) When the output of the NAND gate is given to the input of the NOT gate (made from the NAND gate), then the resultant logic gate works as the AND gate

(ii) Truth table and logic symbol

A	*B*	*Y'*	*Y*
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1



(3) **Construction of the ' OR' gate by the 'NAND' gate**

(i) When the outputs of two NOT gates (obtained from the NAND gate) is given to the inputs of the NAND gate, the resultant logic gate works as the OR gate

(ii) Truth table and logic symbol

A	*B*	$\bar{A}$	$\bar{B}$	*Y*
0	0	1	1	0
0	1	1	0	1
1	0	0	1	1
1	1	0	0	1